

OPTIMIZATION OF THE REINFORCEMENT COVER



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We also thank her for the interest with which she has followed the progress of our work and the development of our knowledge, both technical and general, as well as for giving us the opportunity to do a manual calculation which allows us to detect possible mistakes, which is different from the professional world where you only work with software.

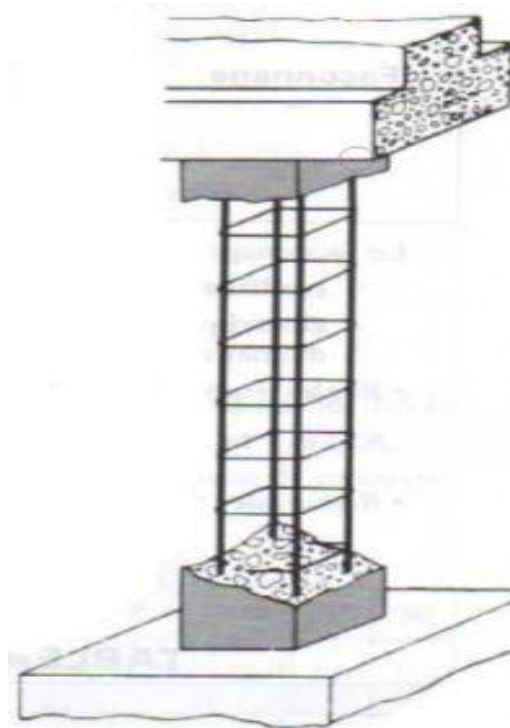
Introduction

Reinforced concrete is a material in which a metal reinforcement (rebar) is used in order to obtain reinforced concrete. True know-how, reinforced concrete thus combines the compressive strength of concrete and the tensile strength of steel. Only for it to be mechanically effective the reinforcement must be judiciously put in place. In addition, the concrete cover must be correct in order to provide protection against aggressive actions that may lead to corrosion of the reinforcements. The coating of the reinforcements and the characteristics of the coating concrete are the fundamental parameters for controlling the durability of structures in the event of corrosion and therefore their duration of use. Therefore, optimizing the performance of the concrete and the coating of the reinforcements constitutes an essential factor of progress to ensure the durability of the structures.

WHERE TO PLACE THE REINFORCEMENT IN A REINFORCED CONCRETE WORK?

♣ CONCRETE POST

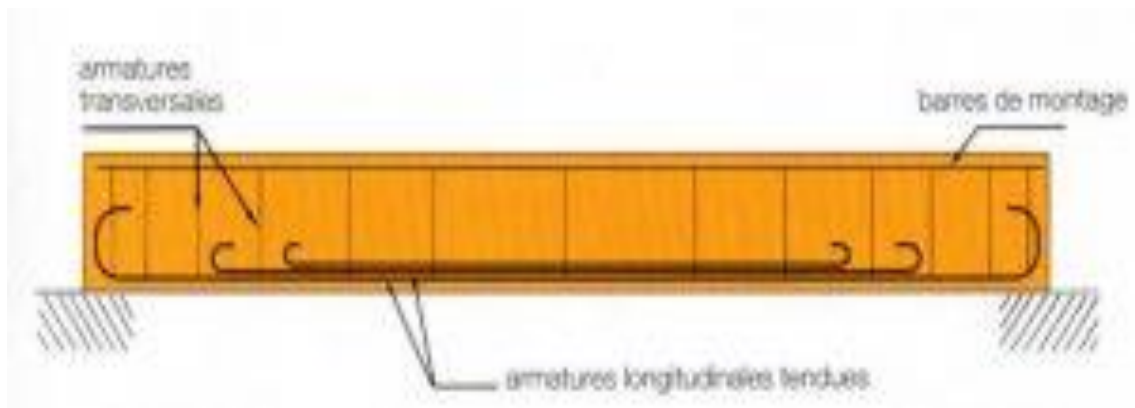
Transverse and longitudinal reinforcements are placed in the columns to make them more resistant to bending and to avoid phenomena such as buckling (the column could flex and bend on one side).



Positioning of reinforcements for a column.

♣ CONCRETE BEAM

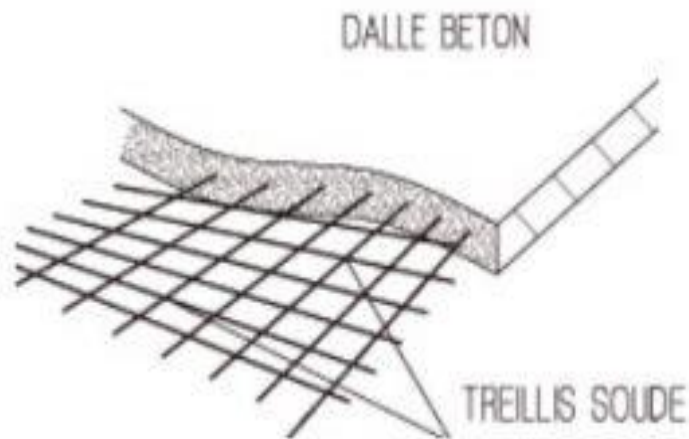
The tensile forces, which are maximum in the lower part, are entirely taken up by the longitudinal steels which are positioned as low as possible, while maintaining sufficient coating.



Positioning of reinforcements for a beam.

♣ CONCRETE SLAB

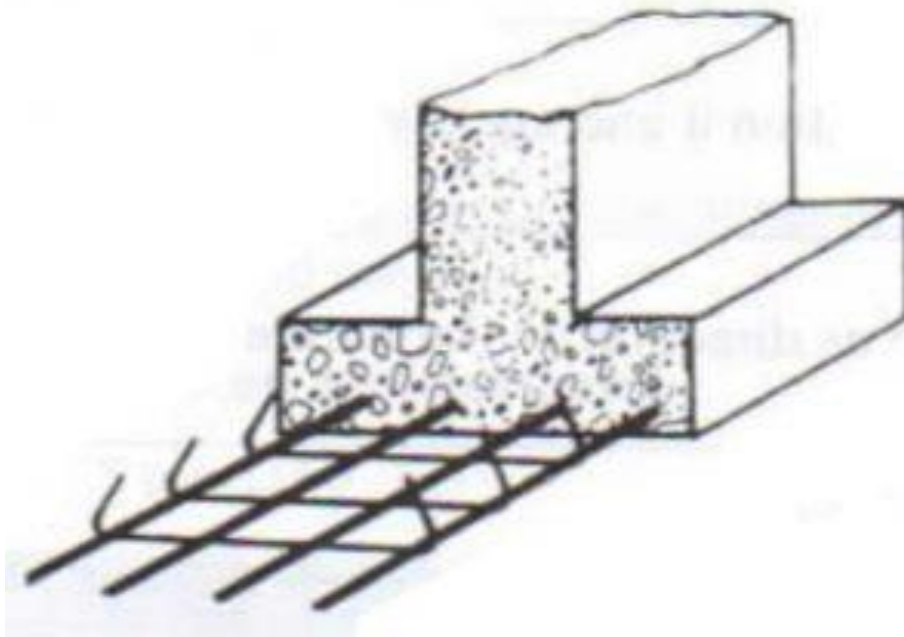
The reinforcement of the welded mesh type is placed in the lower part of the slab, more precisely at the lower 1/3 of the thickness, for the same reason as the concrete beam. This is the typical case of the single-family house slab.



Positioning of reinforcements for a slab.

♣ FOUNDATION SOLE

The reinforcements are systematically placed in the lower part of the foundations (strip footing) to distribute the loads and consolidate the resistance of the foundation concrete to traction.



Positioning of the reinforcements for a continuous sole.

DETERMINATION OF REINFORCEMENT COATING

The reinforcement cover represents the distance between the concrete surface and the nearest reinforcement (frames, stirrups, pins, skin reinforcement, etc.).

It must be sufficient to guarantee:

- good protection of steel against corrosion;
- good transmission of adhesion forces;
- suitable fire resistance.

Thus it is possible to place the reinforcements out of the reach of aggressive agents by protecting them with a sufficient thickness of compact concrete, having undergone an appropriate cure.

The determination of the coating must take into account several factors:

- the exposure classes associated with the part of the structure concerned,
- the duration of use of the project,
- the strength class of the concrete of the structure part,
- the type of quality control system implemented,
- the regularity of the surface against which the concrete is poured,
- the type of reinforcement (passive or active) and their nature (carbon steel, stainless steel),
- mastery of the positioning of reinforcements.

Each part of the work can be submitted on its different sides to classes

exposure to the risk of corrosion.

The editor of the CCTP must therefore, in a specific table (separate from that prescribing the concrete exposure classes), specify the exposure classes to take into account for the determination of the coating of each face of each part of a work (for example, for a veil, the exposure class (es) for determine the coating of the inner face, and the exposure class (s) for determine the coating of the outer face).

Only the nominal coating is specified on the execution plans, as a reference for the manufacture and for the installation of reinforcements. The nominal cover is the sum the minimum cover necessary for durability, established according to the principles of standard NF EN 1992-1-1 and a safety margin for execution tolerances.

The determination of the coatings is the responsibility of the company. Their values must be consistent with the minimum coating of NF EN1992-1-1, and any planned optimizations (compressive strength class higher than the reference class, quality control, type of reinforcement, etc.).

Additional details for determining the coating for structures concrete designed with Eurocode 2 are given in the LCPC Technical Guide "Note Technical on the provisions relating to the coating for application in France".

Nominal cover determination and optimization process

La The value of the coating can thus be optimized in particular:

- ♣ if a concrete is chosen with a compressive strength class greater than the reference class (defined for each exposure class);
- ♣ whether there is a quality control system;
- ♣ if stainless steel frames are used.

The process for determining the coating of the reinforcements in each part of the structure comprises the following 8 steps which will make it possible to successively take into account:

- the exposure class,
- the structural class and the possible modulations according to particular choices,
- the type of reinforcement,
- specific constraints,
- execution tolerances.

♣ Step 1: Consideration of exposure classes



- ♣ Step 2: Choice of the structural class
- ♣ Step 3: Determination of the minimum cover vis-à-vis durability $C_{min,dur}$
- ♣ Step 4: Taking into account the type of reinforcement
- ♣ Step 5: Consideration of specific constraints
- ♣ Step 6: Determination of the minimum coating vis-à-vis the adhesion $C_{min, b}$
- ♣ Step 7: Determination of the minimum cover C_{min}
- ♣ Step 8: Taking into account the execution tolerances

Application on two examples

We will now see 2 examples of optimization of the coating value both concern a part of a structure located in a tidal zone, one in France and the other in Morocco:

✓ The 1st example in France:

We have a part of a structure located in a tidal zone.

• Step 1: Taking into account the exposure class

The exposure classes to be taken into account are:

- XS3: tidal range
- XC4: alternating humidity and drying

• Step 2: choice of the structural class

Structures located on a maritime site are designed for a 100-year project life. They therefore correspond to the structural class S6.

• Step 3: Taking sustainability into account

The value of $C_{min, dur}$ is determined based on the combination of exposure classes and structural class.

Exposure class XS3 and structural class S6: $C_{min, dur} = 55\text{mm}$

Exposure class XC4 and structural class S6: $C_{min, dur} = 40\text{mm}$

• Step 4: Taking into account the type of reinforcement

The use of stainless steel reinforcements reduces the value of the cover. One can take into account a priori a value of $\Delta C_{dur, st}$ equal to 15mm.

- Step 5: Taking into account specific constraints

- o Irregular facings: not applicable

- o Abrasion class

The structure is subjected to sediments carried by the swell, therefore to an abrasion class XM1 which corresponds to a coefficient $k_1 = 5\text{mm}$

- o Concrete poured in contact with irregular surfaces: not applicable

- Step 6: Taking into account adhesion constraints

It is assumed that the maximum diameter of the reinforcement is 40mm and that the diameter of the largest concrete aggregate is less than 32mm.

- Step 7: determination of the minimum cover

The minimum coating is defined in standard NF EN 1992-1-1, section 4 "Durability and coating of reinforcements" (article 4.4.1). In particular, it must meet the requirements for transmitting adhesion forces and protect the steels against corrosion.

It is given by the formula:

$$C_{\min} = \max [C_{\min, b}; C_{\min, \text{dur}} + \Delta C_{\text{dur}}, \gamma - \Delta C_{\text{durst}} - C_{\text{dur, add}}; 10 \text{ mm}]$$

- With $C_{\min, b}$: minimum cover with respect to adhesion requirements (concrete / reinforcement). The value of $C_{\min, b}$ is rarely dimensioning for the determination of $C_{\min}$.

- $C_{\min, \text{dur}}$: minimal coating vis-à-vis environmental conditions. $C_{\min, \text{dur}}$ takes into account the exposure class and the structural class (which depends on the duration of use of the project)

• And:

$\Delta C_{dur, y}$: safety margin (recommended value 0);

$\Delta C_{dur, st}$: reduction of minimum coating when using, for example, stainless steel;

$\Delta C_{dur, add}$: reduction of the minimum coating in the case of additional protections.

The minimum coating with respect to adhesion $C_{min, b}$ is specified in table 4.2 article 4.4.1.2 (3) of standard EN 1992-1-1.

$C_{min, b}$ should not be less:

- the diameter of the bar in the case of individual reinforcement;
- the equivalent diameter in the case of a reinforcement package.

$C_{min, b}$ is increased by 5 mm if the diameter of the largest concrete aggregate is greater than 32 mm.

In this example we have:

- Carbon steel frame
- Stainless steel frame

$$C_{min} = 55 + 5 = 60\text{mm} \quad C_{min} = 55 - 15 + 5 = 45\text{mm}$$

- Step 8 Taking into account the execution tolerances

The minimum coating must be increased, to take into account the tolerances for execution deviation (ΔC_{dev}).

The value recommended in article 4.4.1.3 (3) is $\Delta C_{dev} = 10$ mm unless specifically justified. In particular, this value may be reduced subject to strict quality control conditions both on the design and execution of the works.

The nominal coating is given by the formula:

$$C_{nom} = C_{min} + \Delta C_{dev}$$

If the construction or design and execution of the structural elements are subject to a Quality Assurance system (including in particular specific provisions relating to the design, shaping or installation of reinforcements). It is possible to reduce the value of ΔC_{dev} to a value between 5 and 10 mm.

This possible reduction of ΔC_{dev} makes it possible to encourage better control of the real positioning of the reinforcements and a better quality of production.

So to this example:

ΔC_{dev} will be taken equal to 10mm

from where

$$C_{nom} = 70\text{mm} \quad C_{nom} = 55\text{mm}$$

→ The use of stainless steel reinforcements thus reduces the value of the cover by 15 mm. This results in savings in natural resources (aggregates in particular) and cement.

✓ The 2nd example in Morocco:

We have a part of a structure located in a tidal zone.

Exposure class

- XS3: tidal range;
- XC4: alternating humidity and drying.

Structural class

Structures located on a maritime site are designed for a 100-year project service life (structural class S6).

Consideration of sustainability

The value of $C_{min, dur}$ is determined based on the combination of exposure classes and structural class.

- XS3 / S6: $C_{min, hard} = 55 \text{ mm}$.
- XC4 / S6: $C_{min, hard} = 40 \text{ mm}$.

Type of reinforcement

The use of stainless steel reinforcements reduces the value of the cover. One can take into account a priori $\Delta C_{dur, st} = 25 \text{ mm}$.

Minimum cover

- Carbon steel frame: $C_{min} = 55 \text{ mm}$.
- Stainless steel frame: $C_{min} = 55 - 25 = 30 \text{ mm}$.

Taking into account execution tolerances

$\Delta C_{dev} = 10 \text{ mm}$.

Nominal cover

- Carbon reinforcement: $C_{nom} = 65 \text{ mm}$.
- Stainless steel frame: $C_{nom} = 40 \text{ mm}$.

→ The use of stainless steel reinforcements thus reduces the value of the cover by 25 mm. This results in savings in natural resources (aggregates in particular) and cement.

Conclusion :

The use of stainless steel reinforcements thus reduces the value of the cover. This results in savings in natural resources (aggregates in particular) and cement. So optimization projects will be more efficient if they will be carried out by a design office and by the construction sites.

At the end of this work, we were able to familiarize ourselves with the vocabulary relating to optimization techniques on the one hand; as well as the calculation of the reinforcement cover on the other hand.

In this perspective, this project gave us the opportunity to learn about the techniques used to optimize the coating of reinforcements, which ensures the comfort and safety of users. We hope this project will be a gateway for larger works in the future.

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